Sensorimotor Assessment and Rehabilitation Apparatus: Procedures and Equipment (PI=Schubert)

Completed Technology Project (2013 - 2014)

Project Introduction

NOTE (Ed., 5/5/2014): Continuation (with Michael Schubert as new PI) of "Sensorimotor Assessment and Rehabilitation Apparatus: Procedures and Equipment" due to previous PI Shelhamer's move ; same grant number and period of performance (8/1/2010-7/31/2014) in NASA Shared Services Center information.

UPDATED NOTE (Ed., 6/13/2018): For Task Book purposes, period of performance with Schubert will be 8/1/2013-7/31/2014.

Long-duration flight leads to sensorimotor problems which can be critical during landing, rendezvous, and operations on other planetary surfaces. While specific sensorimotor effects have been identified, it is not known which ones have the most adverse impact, or how best to assess them and apply appropriate rehabilitation procedures. NASA's current goal in addressing this situation is to develop a means to assess sensorimotor function rapidly with a portable device, so that an astronaut can make a determination as to whether or not he or she is impaired enough to affect mission safety or success before undertaking a demanding task (piloting, landing, reentry, egress, extravehicular activity (EVA), tele-operation, etc.).

Accordingly, the goal of this project is to develop a portable hand-held device that will allow a single crewmember to assess his/her sensorimotor function in no more than 20 minutes. This is to be accomplished with a judicious choice of which sensorimotor functions to assess, and careful design to obtain the maximum data in the minimum time. The device and procedures being developed to meet these requirements are based on a tablet computer and body-mounted motion-sensor units. Through a set of simple software routines, a rapid assessment of sensorimotor capabilities will be made. The final device will be small, require little power and space, and provide what is essentially a self-contained sensorimotor lab/clinic. We term this device and its embedded software the Sensorimotor Assessment and Rehabilitation Apparatus (SARA).

SARA has been designed to measure the following functional behaviors, chosen based on laboratory and parabolic flight studies, as being relevant for safe and effective functioning in the space flight environment and likely also to be affected by long-duration space flight:

1. Vestibulo-ocular function during pitching head movements. Subjects actively make pitch head rotation while viewing a target that moves, which they are then tasked to stabilize during the head motion. Without need to record the eyes, this task provides a non-invasive assay of the vestibulo-ocular reflex and canal-otolith integration; highly relevant for gaze stabilization. We term this task the vestibulo-ocular nulling (VON) test.

2. Vestibulo-ocular function as mediated by the otolith organs. We use a binocular display with lines set by the subject to appear collinear or parallel, to measure vertical skew and disconjugate torsion, which are measures of otolith

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asymmetry. This is highly relevant for gaze stabilization and may be predictive of motion sickness susceptibility.

3. Postural control, by measuring body sway with eyes closed. This test is enhanced by having the subject make pitching head movements.

4. Locomotion, by measuring alterations in the coupling between pitching head movements and vertical body motions during walking. We also have subjects perform the 'Timed Up and Go' test and walk heel to toe with eyes open and closed.

5. Dynamic visual acuity. Subjects make active head rotations in pitch (or yaw) at a two different velocity thresholds (60 d/s or 120 d/s) while attempting to identify the orientation of the open segment of the letter 'C' (up, down, left, right). This is highly relevant for gaze stabilization.

Anticipated Benefits

Our sensorimotor assessment apparatus has been implemented on a tablet computer and motion sensors with Bluetooth wireless link. This provides real-time data acquisition and processing of three linear accelerometers and three rate sensors from each of three sensors. This meets the need for rapid non-invasive screening of vestibular and sensorimotor function in settings where special expertise and equipment is not available. Applications include assessment of passengers before and after parabolic and sub-orbital flight, assessment/rehabilitation of vestibular patients away from specialized centers, and assessment of crew immediately on return from the International Space Station (ISS) (on R+0 in Russia).

We believe SARA has a wide range of possible uses for Space and Earth application:

• Go / No-Go decision before any task involving highly-accurate sensorimotor performance

o After landing (moon, Mars, or return from near Earth orbit, NEO) ; o Before EVA (i.e., deep space)

• Data on acute deficits upon return from long-duration stay on ISS

o Inform countermeasure priorities (posture vs. ocular misalignment)

• On board ISS

o Before EVA ; o Correlate assessment with performance

• Field use: rapid evaluation with minimal resources

o Centrifuge studies ; o Before/after suborbital flight

Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Center / Facility:

Johnson Space Center (JSC)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Project Manager:

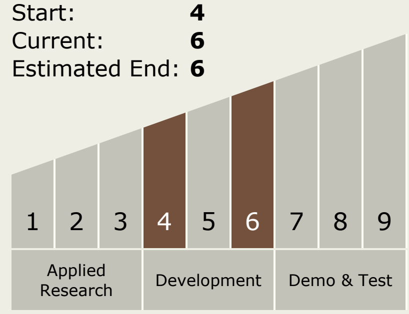
Linda H Loerch

Principal Investigator:

Michael Schubert

Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



• Lab adaptation studies

o Multi-system approach (i.e. study multiple sensorimotor systems simultaneously); o Determination of individual "sensorimotor signature" based on responses from sensorimotor testing; o How do different sensorimotor systems interact together during perturbations and adaptation

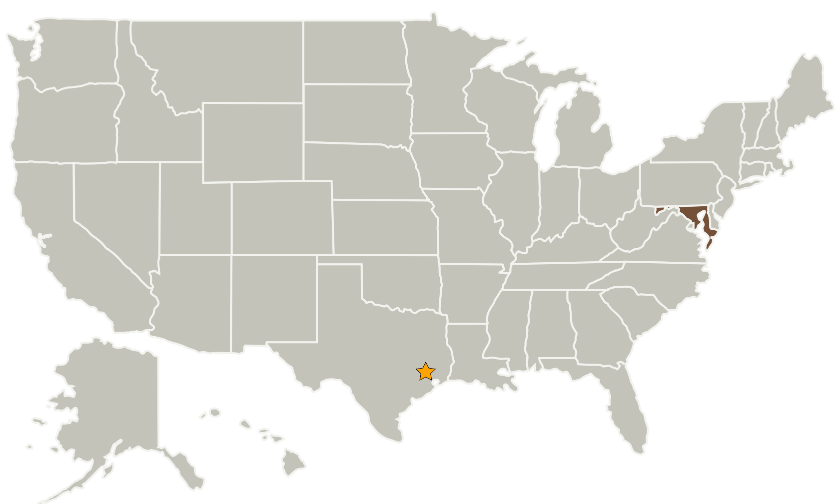
• Clinical Diagnostic

o Identification of patients likely to have peripheral vestibular hypofunction (ocular misalignment, poor dynamic visual acuity (DVA)); o Identification of patients with abnormal sensory processing of vestibular information

• Rehabilitation Treatment

o Provide gaze stability training exercises and monitor compliance ; o Monitor gaze stability (DVA testing, vestibulo-ocular nulling (VON) Testing, Vertical and Torsional Alignment Nulling tests (VAN, TAN)) ; o Provide training regimen for gait/posture training ; o Monitor gait via wireless body worn sensors

Primary U.S. Work Locations and Key Partners



Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  └ TX06.3 Human Health and Performance
    └ TX06.3.4 Contact-less / Wearable Human Health and Performance Monitoring

Target Destinations

The Moon, Mars

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Organizations Performing Work	Role	Type	Location
⭐Johnson Space Center(JSC)	Lead Organization	NASA Center	Houston, Texas
Johns Hopkins University	Supporting Organization	Academia	Baltimore, Maryland

Primary U.S. Work Locations
Maryland

Project Transitions

August 2013: Project Start

July 2014: Closed out

Closeout Summary: As our maturation plan developed (single user, independent testing) over the last year and better LE D (light emitting diode) tablets were available, we realized the critical need to ensure subjects were tested in complete dark (human subjects review approved). Therefore we initially designed a shroud to be built into the side of the aircraft for the p arabolic flight experiments. From November 18-22 2013, we participated in a Parabolic Flight Campaign managed by the Fli ght Opportunities Program. We recruited seven naïve fliers and two highly experienced fliers. Each subject flew one 40-para bola flight. All subjects were screened for motion sickness (none or minimal motion sickness susceptibility on Earth) pre-flig ht, trained in Vertical and Torsional Alignment Nulling tests (VAN, TAN), and participated in baseline data collection. Three o ut of the nine test subjects experienced severe motion sickness (nausea and vomiting), within the first several parabolas of their respective parabolic flights. As such, they were unable to perform the VAN and TAN tests during the actual parabolas. All (n=4) of the naive flyers showed significant g-level dependencies for both VAN and TAN tests (i.e. test scores varied dep ending on 0, 1, or 1.8 g levels). Our experienced fliers did not show any significant differences in g level dependent misalig nments; although this may be partially due to age effects (the two experience fliers were several decades older than naïve t est subjects). Next, we examined all nine subjects' baseline 1g data to look for differences in ocular misalignments between the three individuals who experienced motion sickness inflight and the six who did not. There was no difference in the mean vertical or torsional ocular misalignments between these two groups (VAN: $p = 0.45$ and $r2 = 0.29$, TAN: $p = 0.22$ and $r2 = 0.45$). There was also no difference in the variability of the vertical ocular misalignments between these two groups ($p = 0.19$ and $r2 = 0.48$). There was, however, a strong difference in the variability of the torsional ocular misalignments (two-s ample t-test, $p < 0.001$ and $r2 = 0.92$). This finding is in agreement with a study that correlated instability of ocular torsion during the 0g phases of parabolic flight with spaceflight motion sickness (Diamond et al., 1990). Our data suggests variabili ty in torsional misalignment may be an indicator of motion sickness susceptibility. We are intrigued that this correlation res ult is only observed using the torsion data and not the vertical data. We presume that this is because static torsional eye po sitioning represents a vestigial reflex, much less subject to voluntary control than vertical eye movements. During these No vember 2013 flights, we realized this version of the shroud would be untenable for the goals of our maturation plan. We the refore developed a portable shroud and participated in the July 18-30, 2014 Parabolic Flight Campaign, managed by the Fli ght Opportunities Program. We tested n=12 subjects using our newly designed portable shrouds to measure VAN and TAN i n 1g across different head positions (upright, right ear down, left ear down, supine) and separately across different g-levels (0, 1, 1.8) while positioned upright and during the different g-levels of parabolic flight. Our data suggest most of these exp erienced subjects expressed significant differences in their VAN and TAN responses when upright versus lying supine ($p < 0.05$). All subjects displayed significant differences in VAN and TAN when lying right ear down versus left ear down ($p < 0.0 5$). Parabolic flight-testing revealed that eight subjects showed significant differences in TAN ($p < 0.05$) and seven subjects showed significant differences in VAN ($p < 0.05$) in 0g versus 1.8g. Furthermore, a significant correlation was found betwee n TAN responses inflight and TAN responses on the ground: subjects who showed significant differences in 0g versus 1.8g a lso showed significant differences in upright versus supine. Together, these data can be attributed to innate otolith asymme tries and suggest that VAN and TAN may have a role in identifying deficits in otolith signal processing. Our portable shroud appears to sufficiently enclose subjects in an environment dark enough to ensure accuracy. These data are some of the mo st exciting of our results, as they suggest our VAN and TAN tests of ocular conjugacy can be used to monitor sensorimotor f unction across different gravitational levels. Additionally, this finding existed in both experienced and naïve flyers, suggestin g VAN and TAN have good generalizability regardless of experience. Head Impulse Dynamic Visual Acuity (hiDVA). For the h iDVA test, the subject wears a rate sensor while holding a computer tablet about 18" from the face. Static visual acuity was measured first, followed by dynamic (active head impulse) visual acuity during pitch and yaw head rotation with near (0.45 m) and far (2 m) targets. During each test, subjects viewed optotypes (Landolt C) randomly rotated by 0, 90, 180, or 270 degrees) with Snellen acuity levels between 20/200 and 20/4 (far) or 20/17 (near). For the dynamic component of the test, the letter only flashed when head velocity was > 120 d/s for 80 ms duration. At each acuity level, subjects were presented with five optotypes and asked via forced choice paradigm to identify the orientation. We conducted validation experiments using the head impulse DVA test to ensure the body worn sensor would communicate with the tablet using Bluetooth to trig ger the flashing optotype. Next, we measured static (head still) and dynamic (active head impulse) visual acuity during pitc h and yaw head rotation with near (0.45 m) and far (2 m) targets in 6 healthy controls 4 patients with vestibular hypofuncti on. We found: 1. Patients with vestibular hypofunction had worse DVA for near targets compared with healthy controls ($p< 0.05$). 2. Head motion at near distances confers worse visual acuity than that at far targets in healthy controls ($p < 0.001$). 3. A tablet version of computerized Dynamic Visual Acuity test appears effective at identifying gaze instability. Summary of Human Exploration Research Analog (HERA) and NASA Extreme Environment Mission Operations (NEEMO) Flight Analogs H ERA Objectives: The goals of implementing SARA in the HERA were to validate SARA testing in an operational setting (inclu

Stories

Abstracts for Journals and Proceedings
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Project Website:

https://taskbook.nasaprs.com